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LATULIPPE: A CASE STUDY OF A ONE HUNDRED AND SIXTY KILOMETER RU--ETC(U)

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LATULIPPE:

A CASE STUDY OF A ONE HUNDRED AND SIXTY KILOMETER RUN,

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W.J. O'Hara,
C. Allen,
R.J. Shephard,
J.W. Gill
L.A. Kuehn

Biosciences Division
Defence and Civil Institute of Environmental Medicine
1133 Shepphard Avenue West, P.O. Box 2000
Downsview, Ontario M3M 3B9

DEPARTMENT OF NATIONAL DEFENCE - CANADA

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ABSTRACT

The occasion of a 160 km run by Philip LaTulippe at CFB Toronto during May 24-25, 1974, provided an opportunity for DCIEM scientists to document the physiological changes occuring in the 55-year old athlete during such an unusual endurance feat and, in part, to determine how it was that such an older individual could complete a physical event beyond the capacities of most younger men. LaTulippe ran the course in 20 hours at an average speed of 8.16 km/h with an estimated energy output of 59.1% of his maximum oxygen intake. His heart rate was monitored by telemetry and the average rate for the final four hours (125 beats/min) was not increased relative to speed and oxygen consumption for this portion of the run. Calculations of fluid balance suggest that water needs were met by fluids ingested every twelve minutes after the first four hours of running, such fluids consisting of water, tea/syrup, beef broth, mushroom soup and ice cream/syrup in rotation. Caloric intake averaged 480 kcal/h, giving a deficit of some 56 kcal/h.

INTRODUCTION

At age 55, a time of life normally devoted to reflections of retirement, it is surprising that certain individuals undertake rigorous physical training to the degree that they are able to compete and set records in extremely long distance events. To encounter such an individual is a rare occasion, but even rarer is the opportunity to examine him scientifically during the course of a long distance run. Such an opportunity occurred at DCIEM when a 55-year old long-distance runner and world record holder agreed to run a distance of 160 km (100 miles) under scientific supervision. Such supervision was intended to document the physiological changes in the athlete as a consequence of his physical efforts in an attempt to determine how a man of his age could complete a physiological feat beyond the capabilities of most younger men.

A similar study (Shephard et al, 1976), of an athlete aged 47 years, concluded with the suggestion that the major factor limiting endurance performance is the ability to ingest the necessary caloric energy while running. The study described in this paper afforded another opportunity to examine this hypothesis.

METHODS

Subject and experimental plan - The 55-year old male Canadian subject, Philip LaTulippe, had established two years previously an unofficial world record by running 480 km in 77 hours. Since that time, he had maintained his physical condition by running 80 to 160 kilometers every week.

He agreed to be a scientific subject in a run of 160 km at CFB Toronto, commencing at 1400 hours on May 24, 1974, and concluding 20 hours later at 1000 hours the following morning. The run took place on a quarter-mile cinder track during cool spring weather, and required 400 successive laps for completion.

The first four hours of activity were totally uninterrupted. Thereafter, the subject slowed to a walk every 12 minutes for the ingestion of fluid (water, beef broth, mushroom soup, an ice-cream/ syrup mixture and a tea/syrup mixture were taken in rotation). Brief (2.5 min) halts for physiological monitoring were made after 3.5, 5.25, 6.75, 9.0, 11.0, 13.0 and 17.5 hours of running.

Detailed measurements of cardio-respiratory fitness were made a few days prior to the run. Observations over the course of the event included repeated measurements of body weight, skinfold and skin thickness, blood pressure, heart rate, core temperature, blood chemistry, urine output and composition and thermographic assessment of the skin temperature of his legs.

Environmental conditions - Ambient meteorological conditions were monitored by wet bulb (WB), dry bulb (DB) and globe (GT) thermometers for the purpose of determining the heat stress encountered during the run, as defined by the formula of the Wet Bulb Globe Temperature (WBGT) index (Yaglou and Minard, 1957):

$$WBGT = 0.7\ WB + 0.2\ GT + 0.1\ DB$$

Laboratory techniques - The maximum oxygen intake (VO_2 max) was measured directly, using a standard progressive treadmill protocol (Shephard et al, 1968). The vital capacity (VC) and one second forced expiratory volume (FEV_1) were determined by standard spirometry (Weiner & Lourie, 1969). Handgrip force was measured by a Stoelting dynamometer. Cardiac output and related variables were measured on the bicycle ergometer, using a CO_2 rebreathing method (Jones et al, 1975). A standard 12-lead electrocardiogram, with X, Y, and Z derivatives was obtained two hours before and 30 minutes after completing the run.

Field measurements - Body weight was measured with a medical balance scale, accurate to 50 g; the subject wore shoes, shorts and a telemetry transmitter during all readings, and a correction of 1.2 kg was applied for these items. Skinfold thickness was measured at four marked sites (triceps, suprailiac, subscapular and abdominal folds), using Harpenden skinfold calipers (Weiner & Lourie, 1969). Skin thicknesses were measured on the dorsum of each hand, using the same calipers. Heart rate was monitored continuously during the run using a Siemens Telecust 36 telemeter. Core temperatures were monitored by an intra-gastric radio pill (Brox and Ackles, 1973). Blood pressure was measured with a standard sphygmomanometer cuff from the right arm, after one minute of seated rest. The oxygen cost of running was measured with a Kofranyi-Michaelis respirometer during training periods.

During each field stop, the legs of the subject were photographed with an AGA Thermovision infrared imaging camera for documentation of the surface temperature changes occurring as a consequence of running.

Biochemical measurements - Serum samples were analyzed for calcium, inorganic phosphorus, glucose, urea nitrogen, uric acid, cholesterol, total-proteins, albumin, total bilirubin, alkaline phosphatase, lactic dehydrogenase and SGOT (SMA-12 Autoanalyzer).

Urine samples were examined for volume, specific gravity, pH, protein and ketone body content (Labstix reagent strip), sodium, potassium and chloride ion concentration.

RESULTS

Initial status - The runner was 174.5 cm tall and weighed 61.3 kg, some 3 kg less than the actuarial "ideal" for his size. Skinfold readings indicated a low percentage of body fat (average of four fold was 7.1 mm, equivalent to 12.7% body fat by the equations of Durnin & Ramahan, 1967).

The VC was 4.63 L BTPS, 106% of the age-related normal figure. The FEV_1 was 3.64 L BTPS, compared with a predicted figure of 2.40 L; the FEV_1/VC ratio was 79%.

The cardiac output was 13.3 L/min at a workload of 100 Watts and 15.5 L/min at 150 Watts, these figures corresponding to stroke volumes of 110 and 103 ml, and to arterio-venous oxygen differences of 9.0 and 12.2 ml/100 ml respectively.

The maximum workload attained on the bicycle ergometer was 183 Watts, at a heart rate of 161 beats/min. The corresponding oxygen consumption was 2.77 L/min, 43.6 ml/kg.min STPD, with a respiratory gas exchange ratio of 1.15. During uphill treadmill running, the maximum oxygen intake was increased by 14.8% (3.18 L/min, 30.5 ml/kg.min STPD).

Handgrip force (45 kg) was not outstanding.

Running efficiency - Trials of oxygen cost of running were conducted on a cool February day some three months prior to the main run. Ambient temperatures were about 2°C. The subject ran 16 kilometers, at a steady speed of some 10.7 km/h. The heart rate, as measured by telemetry, averaged 146.4 beats/min over this course; extreme values were 138 and 154 beats/min, with no systematic tendency to an increase of heart rate from the early to the late stages of the run.

The oxygen consumption was measured over the final 3.2 km. The observed oxygen expenditure of 2.31 L/min (36.7 ml/kg.min STPD) was 5.9% lower than the predicted value for average young adults (Shephard, 1968), and amounted to 72.5% of the subject's VO_2 max.

Environmental conditions - Ambient climatic conditions during the 160 km run are shown in Figure 1. Dry bulb temperature ranged from 6.1 to 18.9°C (43 to 66°F); wet bulb temperature from 4.4 to 12.2°C (40 to 54°F) and globe temperature from 4.4 to 29.4°C (40 to 85°F). During the night, the globe temperature fell below the dry bulb temperature, indicative of radiative heat loss to the night sky and the reverse of the situation during the day when the runner was the recipient of solar radiation. Such a condition was beneficial to him during his night run, allowing him greater ease of thermo-regulation, already aided by low dry and wet bulb temperatures. The climatic variation during the day was due to periods of cloud.

WBGT calculations in excess of 26.7°C (80°F) are considered thermally uncomfortable and those in excess of 29.4°C (85°F) are considered thermally hazardous. As shown in Figure 1, the heat stress encountered during the run was never thermally uncomfortable or hazardous. Wind speed varied from 5 to 27 km/h (300-1500 ft/min) and relative humidity varied from 46 to 81%. The running conditions were judged to be excellent, especially in consideration of the fact that over 50% of the running took place at night during cooler climatic conditions.

Performance in the 160 km run - The total running time for the 160 km was 1177 min, corresponding to an average speed of 8.16 km/h. The oxygen cost in an average subject would amount to 32 ml/kg.min, but allowing for the increased efficiency of running, the oxygen consumption of LaTulippe would have averaged no more than 30 ml/kg. min, 1.88 L/min, or 59.1% of maximum oxygen intake.

Speed slowed progressively over the twenty hours of observation. The minute lap times shown in Figure 2 equate to running speeds of 10.6 km/h at two hours, 9.9 km/h at 8 hours, and 7.6 km/h at 18 hours. The heart rate showed corresponding variations (Fig. 2), reaching a peak of 160 beats/min in the first half an hour of activity, but thereafter showing a steady decline to 125 beats/min for the final four hours. The average heart rate for the complete run was 141 beats/min, corresponding fairly well with his estimated usage of 59% of aerobic power.

The initial body core temperature was 36.7°C. At no point during the run did the recorded value rise above 37.4°C. Figure 3 shows the progressive changes in leg skin temperature as measured by the infrared imaging camera relative to a control assessment made in comfortable laboratory surroundings (Pose 1). The times at which Poses 2 to 10 inclusive were obtained are indicated in Figure 1. During the early part of the run, the leg skin temperature increased markedly, particularly over the lateral aspect of the quadriceps femoris, the dorsi-flexors of the ankle and the gastrocnemius, reaching a maximum intensity at Pose 4 (5.25 hours after start of the run or 1925 hours clock time). Thereafter the temperatures decreased during the cool night phase of the run, increasing again after sunrise (Pose 10). Particularly interesting are the results for Pose 4 which were taken shortly after the first caloric ingestion of the run. The region of the abdomen overlying the liver increased greatly in temperature. This observation undoubtedly reflects the elevated internal temperature induced by the enhanced metabolic processes occuring in the liver as a consequence of having run continuously for 4 hours prior to the ingestion of his first nutritive substance.

The initial systemic blood pressure was 140/77 mm Hg. This

was fairly well sustained over the run, pressures being 115/74 mm Hg at 4 hours, 115/75 mm Hg at 13 hours and 125/70 mm Hg 30 minutes after completion of the run.

The pre-race electrocardiogram showed a regular rhythm, but with negative P waves in leads II and III, suggesting either an upper nodal or a coronary sinus rhythm. This dislocation of the pacemaker disappeared over the course of the run, and did not reappear in the ECG taken at the thirtieth minute of recovery.

Fluid and energy balance - The fluid and food intake is summarized in Table 1. Nothing was ingested over the first four hours of the run. Thereafter, fluid was ingested at an average rate of 592 ml/h. The quantity of fluid taken was largest at the stops where water was provided, and was least for mixtures containing ice-cream, syrup and milk. In contrast, the caloric intake was greatest when the ice-cream mixture was taken, and was least when the beef broth was provided. The total energy intake was estimated at 7695 kCal (32 MJ) or 481 kCal/h (2.0 MJ/h).

Body weight declined 3.9 kg during the first four hours of the run. Thereafter it increased steadily until at the conclusion of the run it was 1.85 kg greater than the initial weight (Fig. 4). The weight of food and water ingested was 10975 g. Assuming an energy yield of 4.85 kCal/litre of oxygen, the total cost of the run was estimated to be 10732 kCal. This could be met by the consumption of 800 g of fat (9.0 kCal/g) and 929 g of carbohydrate (3.8 kCal/g), yielding 750 and 557 g of water respectively for weight losses of 50 and 372 g. Other sources of weight loss were urine formation (1197 ml, 1233 g), respiratory water vapour loss (2110 g total), faecal loss (approximately 500 g) and by difference, sweat production of 4860 g, 243 ml/h. The low rate of sweating is attributable to the relatively cool environmental conditions, with radiant heat loss during the night hours.

Some 1197 ml of urine was voided over the course of the run. Metabolic water production was approximately 1300 ml, while combustion of tissue glycogen reserves could have liberated as much as 1600 ml of water; on this basis, water income would have exceeded water loss by some 3807 ml over the run.

Assuming a yield of 1600 kCal of energy from stored glycogen during the first four hours of running, the cumulative energy deficit for the 20 hour period would be about 1437 kCal. During the period of food ingestion, the deficit was only 55.6 kCal/h, 232 kJ/h. In support of the relatively good energy balance, skinfold readings did not show any diminution in thickness over the run. Initial values averaged 7.08 mm, and the corresponding figures at four, eleven, and twenty hours were 6.70, 7.00 and 7.38 mm. Skin thicknesses were in-

itially 2.4 mm, with readings of 2.5 mm at 11 hours, and 2.85 mm at 20 hours.

Blood chemistry - The biochemical results are shown in Table 3. Blood glucose levels were still high in the seventh hour of the run, and thirty minutes after the event they were normal. Seven hours after the run began, and three hours after the first ingestion of food, blood glucose was maximal at 139 ml/100ml. Thirty minutes after the run, blood glucose had returned to pre-run values. Urea nitrogen showed a small increase during and immediately after the run, indicating some continuing protein metabolism, possibly coupled with a reduction in renal clearance of urea. There was a rise of cholesterol during the event with a fall immediately after the run which was still sustained 24 hours later.

As in other distance events, very large increases of serum SGOT and LDH were registered, these changes persisting 24 hours after the run. There were no overt symptoms or signs of muscle injury either during or following the event.

Urinalysis - The subject urinated throughout the run at irregular intervals denoted by the stops indicated in Figure 1. Specimens were relatively concentrated, the specific gravity averaging 1.030, with extremes of 1.024 and 1.034. The maximum specimen volume was 157 ml, with a urine flow of 32 ml/h over the first four hours, and thereafter a gradual increase to about 95 ml/h (Fig. 5).

Sodium and chloride excretion decreased during the first four hours of activity, but increased to more than twice the resting rate of elimination once fluid intake commenced (Fig. 6). Potassium excretion was greater than the previous resting level throughout the run. Ketone bodies were not present during the event, but they were found in fairly heavy concentrations immediately following the run. Proteinuria was not a significant feature either during or following the bout of exercise.

DISCUSSION

Initial characteristics - Although taller than many of his peers, the subject had many of the physical characteristics of the ultra-long distance runner, including a light body weight and a low percentage of body fat. While handgrip force was not outstanding, lung volumes were better than those for an average man of his age. The stroke volume and cardiac output during sub-maximal bicycle ergometry were essentially normal, but the maximum oxygen intake was 53% above the Toronto average for a sedentary individual of comparable age (Shephard, 1976). Good use was also made of the available oxygen transport, running efficiency being 5.9% greater than found in average young men.

Performance in the run - Industrial physiologists have recommended that in order to avoid fatigue, oxygen usage should not exceed 40% of aerobic power over an eight hour day (Astrand, 1960, 1967; Bonjer, 1968; Shephard, 1976), or 64% over a two hour stint. The energy usage in the marathon race is usually somewhat greater than the industrial recommendation, 75% of aerobic power being sustained for more than two hours of activity (Costill, 1970; Kavanagh & Shephard, 1977). Nevertheless, it seems an exceptional achievement for a 55-year old man to sustain the use of 59% of his maximum oxygen intake over a twenty hour period.

It is further remarkable that despite the intensity of effort, the heart rate did not show a progressive increase over the run. While there was some slowing of running speed over the twenty hours, the heart rate of 125 beats/min seen in the final four hours of the event would have been anticipated as an early response to the oxygen usage of this period (56% of maximum oxygen intake). The ability to sustain a low heart rate is presumably an expression of training for ultra-long distance running, although other favourable factors included cool weather and the maintenance of plasma volume through a large fluid intake.

Fluid balance - The water intake, 9474 ml over 16 hours, or 592 ml/h, compares quite favourably with 800 ml/h reported by Costill (1972) for subjects who drank 4 - 5% glucose solutions over much shorter periods of time. It is substantially better than the 250 ml/h accomplished by a cross-Canada runner (Shephard et al, 1977), but this seems due mainly to rotation of the fluids provided, intakes ranging from 320 ml/h for the ice-cream/syrup mixture to 740 ml/h for plain water.

The calculations of water balance are at first glance a little puzzling, in that a positive balance of some 3807 ml was apparently accumulated over the twenty hour run. While continued urine flow shows that a good fluid balance was sustained, the plasma composition does not suggest that there was extensive haemodilution. One likely source of error in the calculations is an accumulation of sweat in the shorts of the runner; this could easily account for 250 ml of fluid. It is also possible that between one and two litres of fluid were ingested but not absorbed over the course of the event; the four bowel movements towards the end of the run support the idea that some gastric distension occurred. Lastly, there was undoubtedly some fluid accumulation within the active tissues; muscles can show a 20% gain of volume through accumulation of tissue fluid during sustained activity (Shephard, 1972). The replacement of this exudate could account for the absence of drift in the heart rate.

Energy balance - The caloric intake accomplished by rotation of fluids averaged 480 kCal/h, 2.01 MJ/h; this was better than was accomplished with any of the food mixtures tested on a cross-Canada runner

(Shephard et al, 1977), and also compares favourably with the 152 kCal, 635 kJ, yielded by 800 ml of 5% glucose.

Over the sixteen hours that food was being ingested, the apparent energy deficit was no more than 55.6 kCal/h, 232 kJ/h. The actual deficit would have been somewhat larger if not all of the fluid was absorbed. The high blood glucose readings, the unchanged skinfold thicknesses, and the absence of ketonuria during the run all suggest that the subject was in positive energy balance.

The rise of blood urea was substantially smaller than that observed in marathon events (Shephard et al, 1977). This may reflect not only the good energy balance, but also the fact that the 160 km run was conducted at a smaller fraction of maximum oxygen intake, with a corresponding reduction in the proportion of anaerobic work.

Ideal fluid - The present data show that under cool conditions it is possible to ensure a substantial caloric intake while meeting fluid needs. However, in a hotter environment, it may be conjectured that it becomes necessary to decide whether calories or water needs are the determinant of performance, and to modify the fluid supplied accordingly. If the problem is dehydration, the best antidote seems to be pure water (Shephard et al, 1977).

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TABLE I

FLUID AND WATER INTAKE* OVER 160 KM RUN

Preparation	Weight (g)	Caloric yield kCal/g	Total calories (kCal)	Percentage moisture (%)	Total water (ml)
Tea, syrup sugar	2002	0.76	1522	81.9	1638
Beef Broth	1660	0.08	133	96.2	1597
Mushroom soup with milk	2368	1.06	2510	83.3	1974
Ice cream with syrup & milk	1972	1.70	3530	65.6	1292
Water	2973				
Total intake	10975		7695		9474

* Items were administered in rotation at 12 minute intervals, commencing in the fifth hour of running, and continuing to the twentieth hour.

TABLE 2

FLUID AND ENERGY BALANCE FOR THE 160 KM RUN

Energy Balance:

Food and water ingested	10975 g	gain
Combustion of mixture of 800 g fat and 929 g carbohydrate to 1307 ml water	422 g	loss
Urine 1197 ml, sg 1.030	1233 g	loss
Respiratory water vapour	2110 g	loss
Faeces (4 bowel movements)	500 g	loss
Sweat production	4860 g	loss
Net body weight gain	1850 g	

Water Balance:

Fluid intake	9474 ml
Metabolic water production	- 1300 ml
Glycogen release	- 1600 ml
Total water intake	12374 ml
Urine output	1197 ml
Respiratory water loss	2110 ml
Faecal water loss	400 ml
Sweat loss	4860 ml
Total water loss	8567 ml
Positive water balance	3807 ml

TABLE 3

BLOOD CHEMISTRY RESULTS

CHEMICAL TEST	RESULTS			
	2 HOURS PRE-RUN	7 HOURS INTO RUN	30 MINS POST RUN	24 HOURS POST RUN
Calcium (mg/100ml)	10.3	10.8	9.3	9.0
Inorganic Phosphorus (mg/100ml)	3.2	4.2	3.6	2.2
Glucose (mg/100ml)	105	139	109	102
Urea Nitrogen (mg/100ml)	27	37	35	23
Uric Acid (mg/100ml)	4.7	6.3	5.4	5.0
Cholesterol (mg/100ml)	265	285	210	207
Total proteins (g/100ml)	7.4	7.5	6.2	6.5
Albumin (g/100ml)	4.74	4.82	4.01	4.14
Total Bilirubin (mg/100ml)	0.6	0.8	0.9	1.1
Alkaline Phosphatase (U/L)	60	85	82	69
LDM (U/L)	194	293	363	293
SGOT (U/L)	51	83	370	200

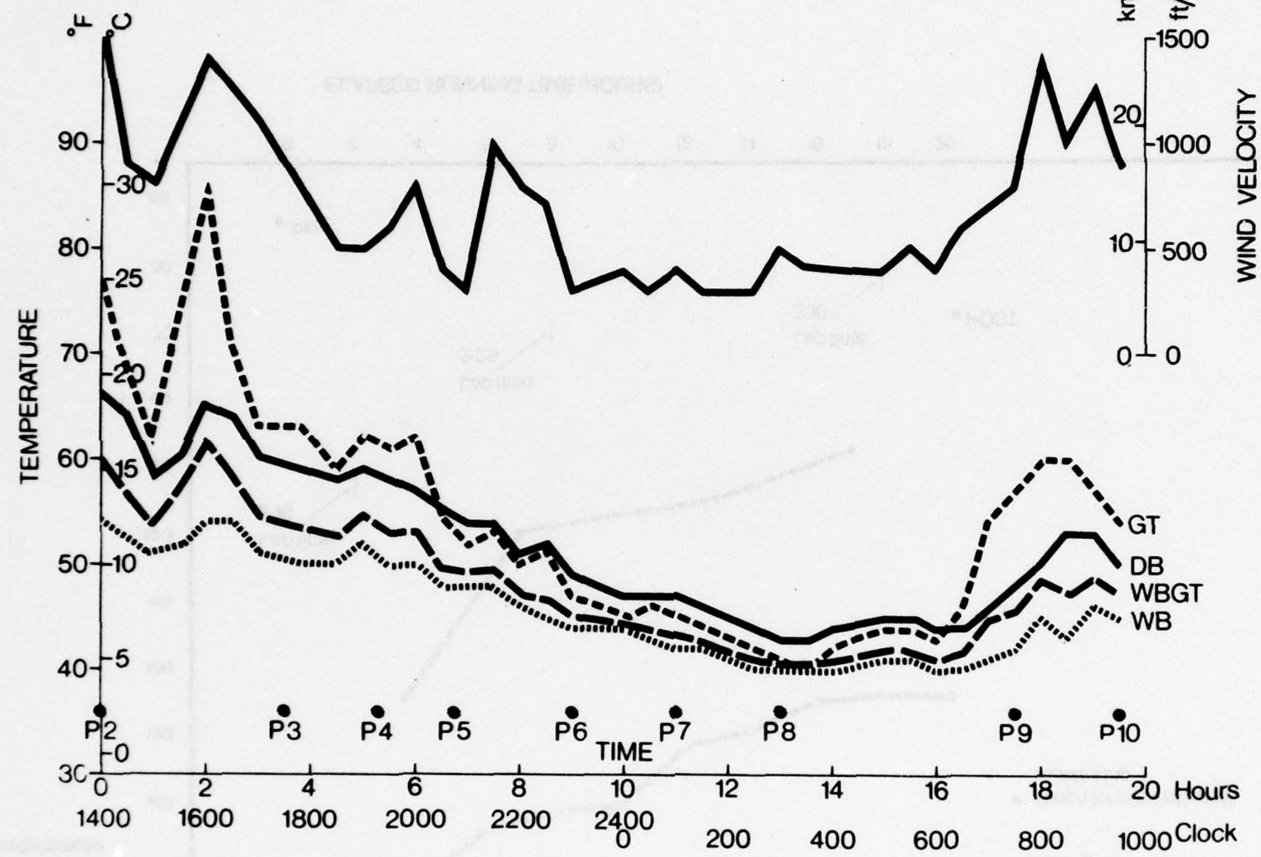

Figure 1: Climatic conditions during the run. The letters P2 to P10 denote stops for physiological monitoring.

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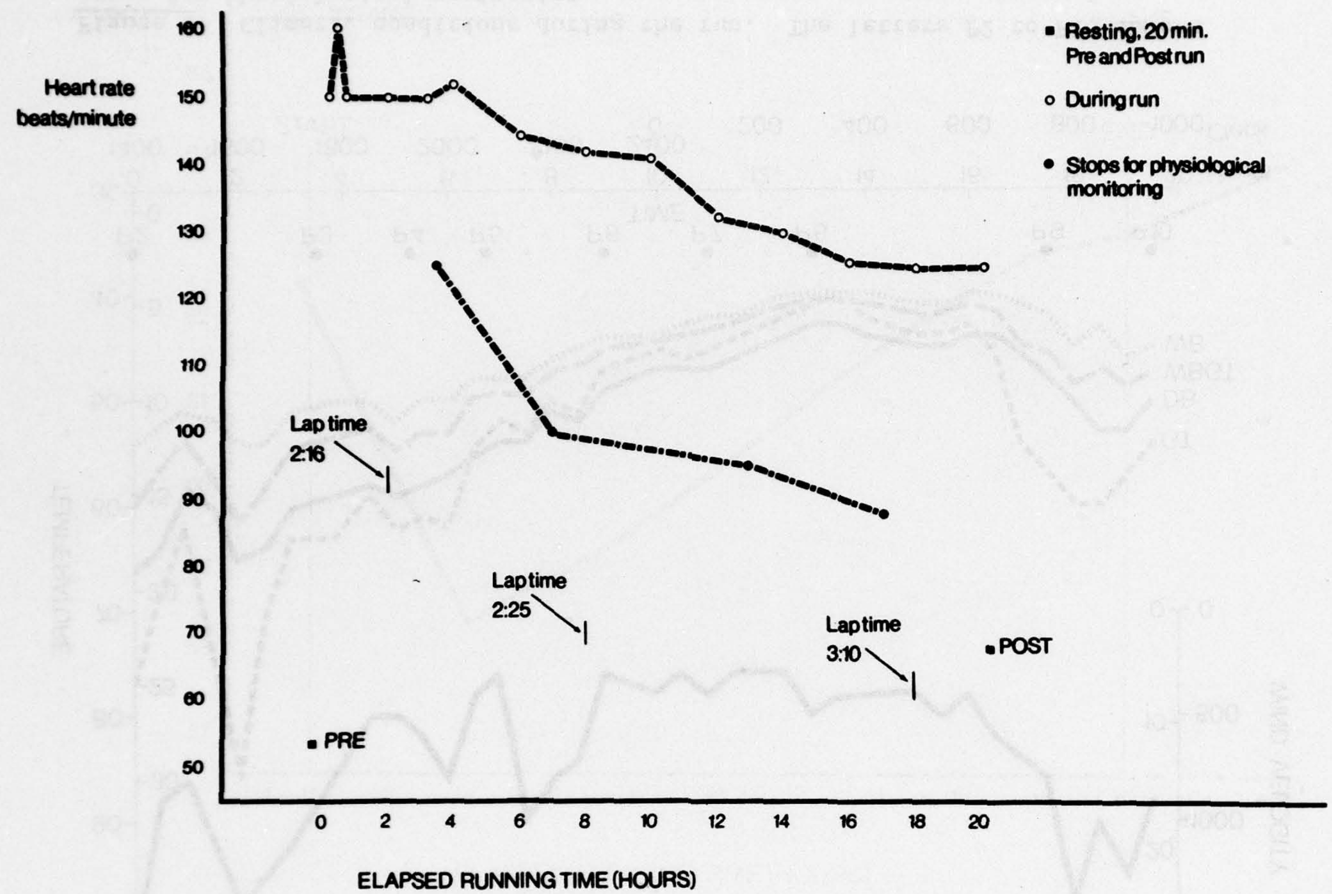

Figure 2: Telemetered heart rate during the run, and after resting for 2.5 min during halts for physiological monitoring.

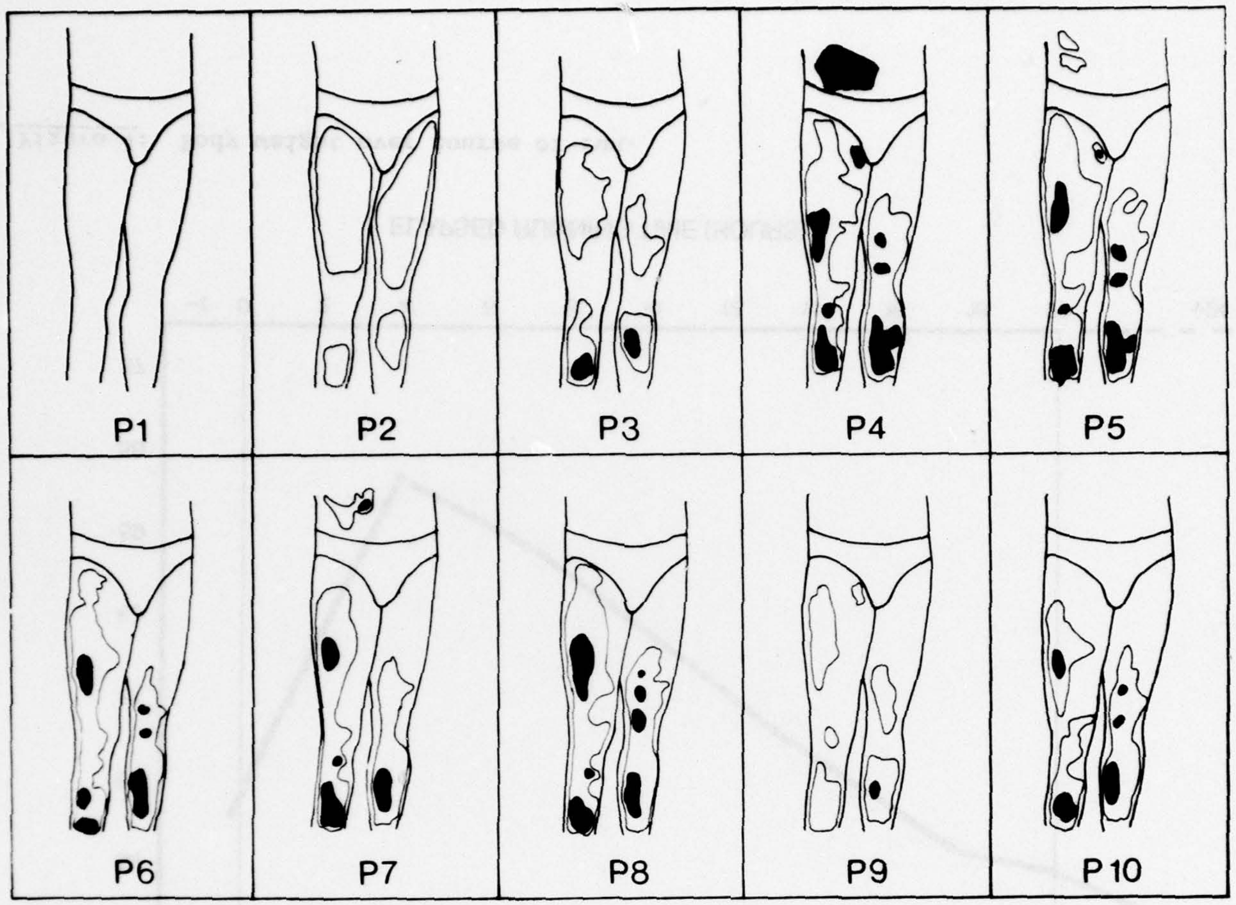

Figure 3: Skin temperatures measured with AGA Thermovision infrared imaging system at stops P2 to P10 with reference to control measurement in comfortable laboratory surroundings, P1. In P1, the mean temperature of the legs was uniformly near 32°C. The clear empty isotherm depicted in P2 denotes 34°C and the cross hatched isotherm first observed in P3 denotes temperatures equal or higher than 36°C.

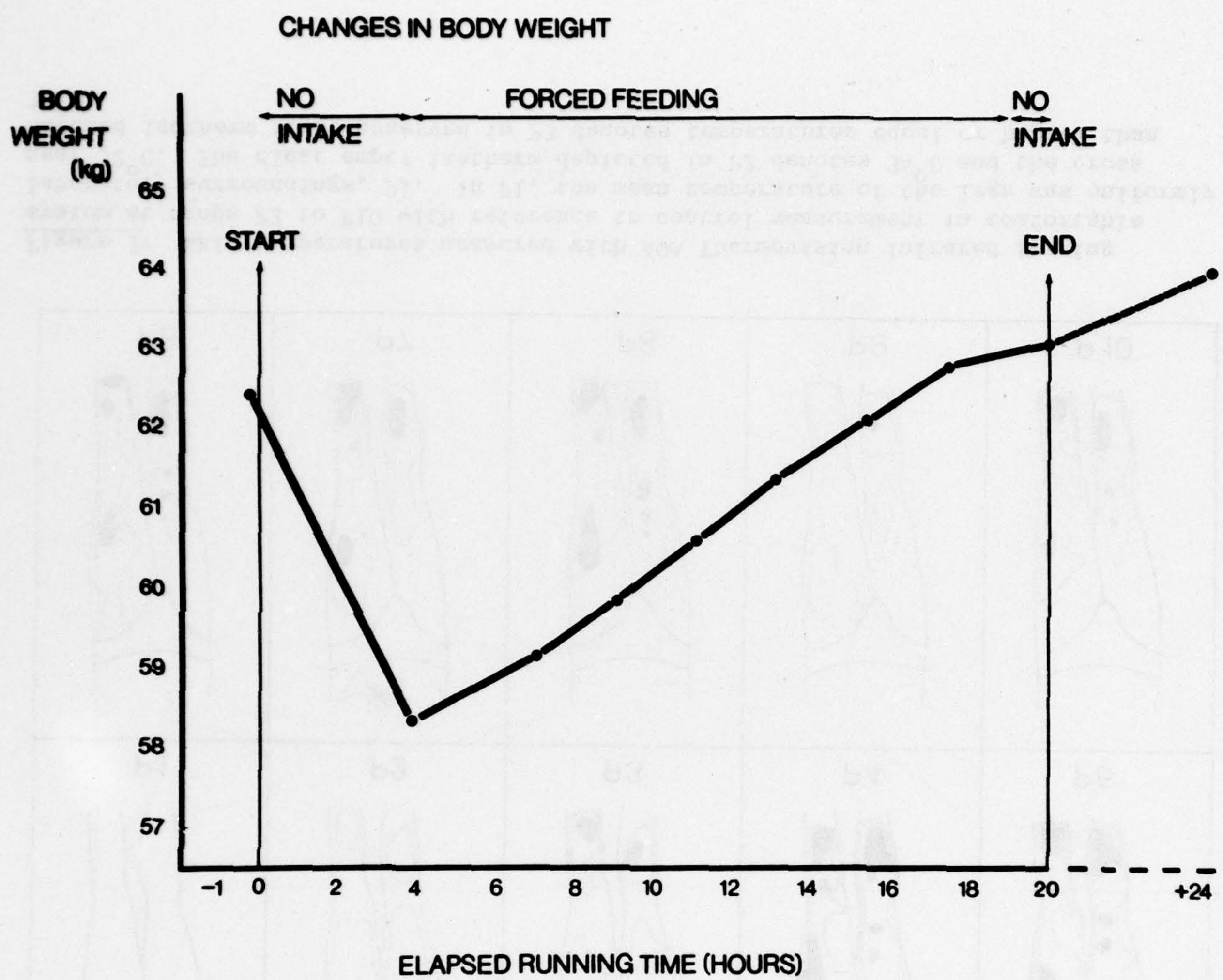

Figure 4: Body weight over course of run.

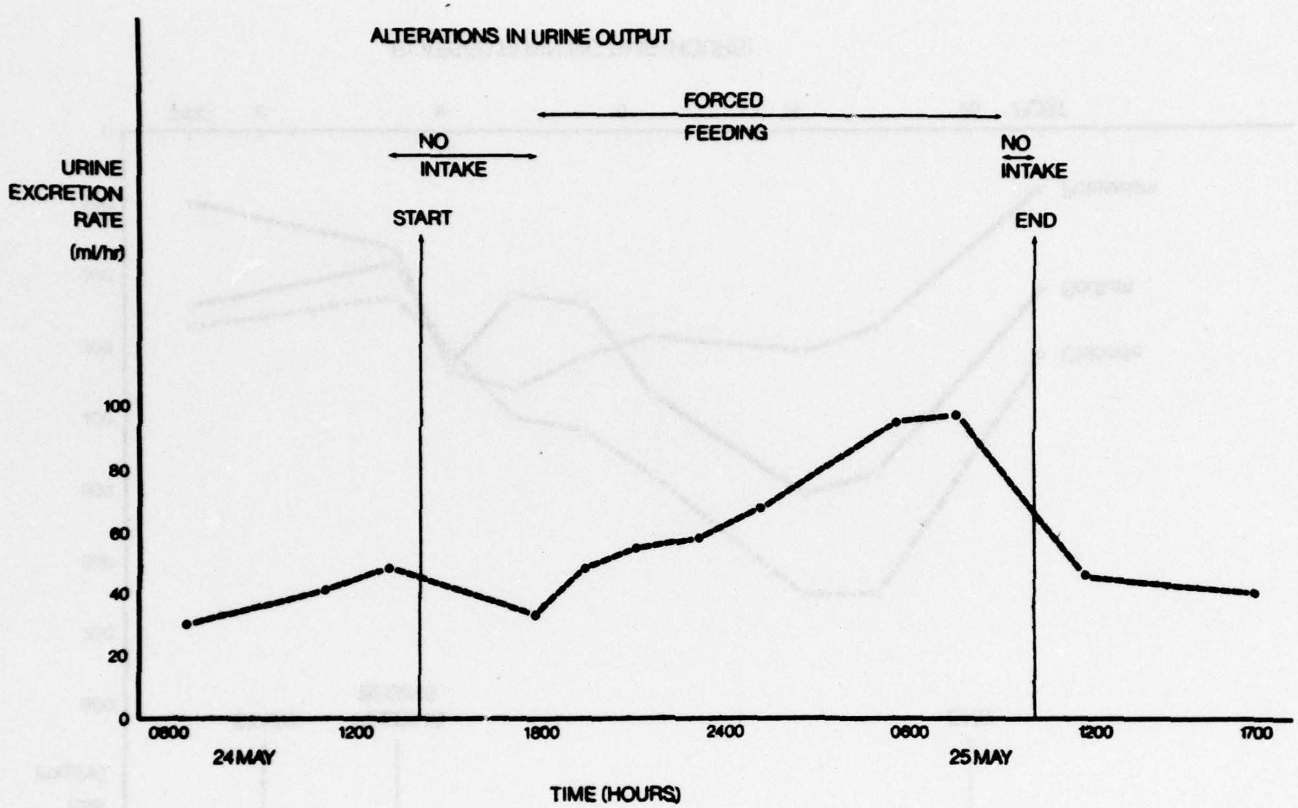

Figure 5: Urine flow over course of run.

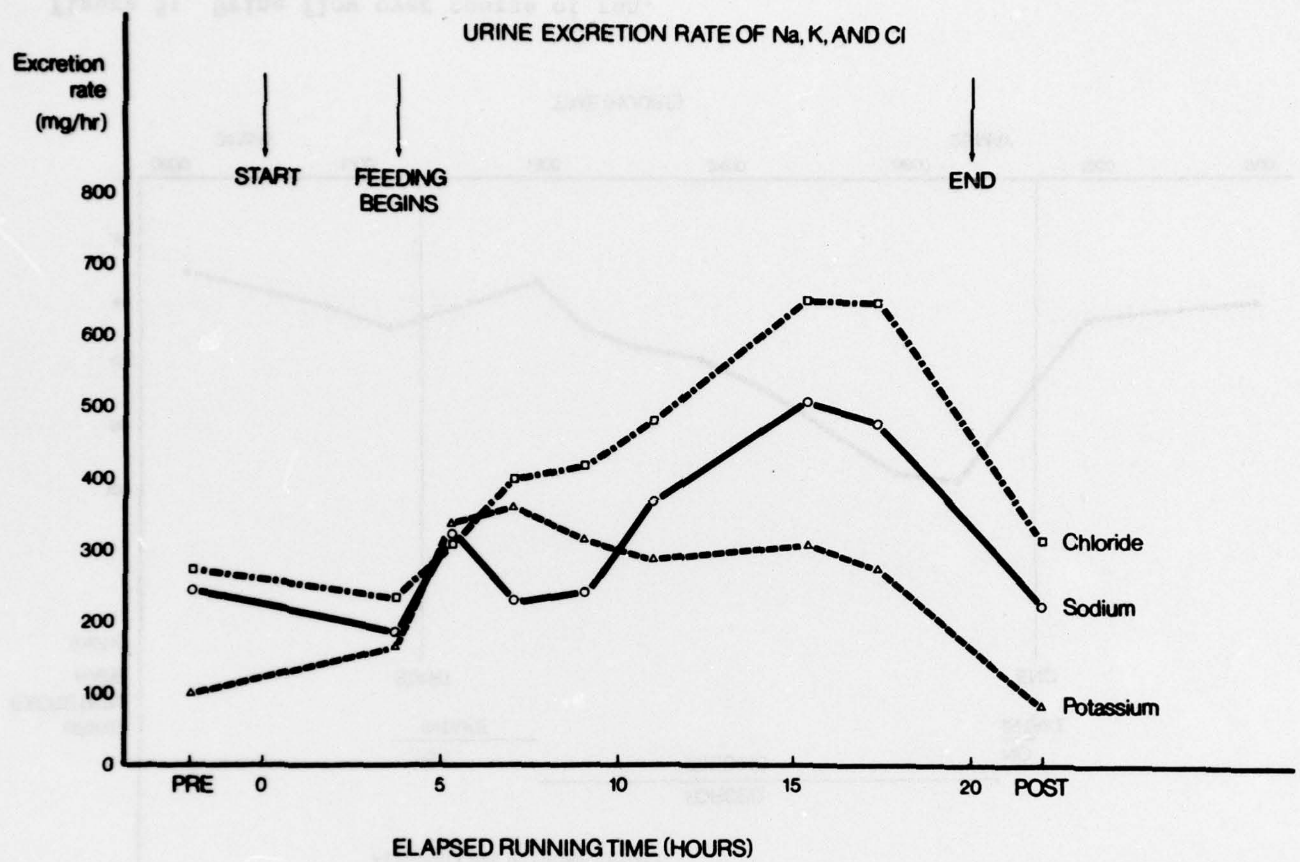

Figure 6: Urinary excretion of potassium, sodium and chloride over course of run.